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A Study of Ground Water Quality for Irrigation Purposes in SIDCUL-Rudrapur of Udham Singh Nagar District, Uttarakhand

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Abstract The present study was conducted to study suitability of ground water for irrigation purposes. The water samples for the physico-chemical analysis were collected from the deep and shallow hand pumps of the 24 locations of SIDCUL (State Industrial Development Corporation Uttarakhand Limited) near Rudrapur of Udham Singh Nagar district, Uttarakhand to analyzed for Mg:Ca ratio, Percent Na, Exchangeable sodium percentage (ESP), Sodium absorption ratio (SAR) and Soluble sodium percentage (SSP). The categorization of the ground water for irrigation was studied with the help of standard criteria. The study revealed that two out of 24 water samples were found under C_3 class of salinity which implied that the water from these places was highly saline. One out of 24 and two out of 24 were found unsuitable on the basis of percent sodium and under permissible category on the basis of electrical conductivity. Two out of 24 were found to have slight to moderate effect on availability of water to crops on the basis of salinity and Nine out of 24 water samples were having no toxicity effect while other samples were having slight to moderate effect of ion toxicity on the basis of SAR ratio.

Keywords Physico-chemical, Electrical conductivity, Percent sodium, SAR, Salinity.

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Introduction

Groundwater is one of the most valuable natural resources, which supports human health, socio-economic development and functioning of ecosystems[1, 2]. Groundwater is generally less susceptible to contamination and pollution when compared to surface water bodies. In India, where groundwater is used intensively for irrigation and industrial purposes, a variety of land and water-based human activities are causing pollution of this precious resource. Water pollution is the contamination of water bodies such as lakes, rivers, oceans and groundwater [3]. It occurs when pollutants are discharged directly or indirectly into water bodies without adequate treatment to remove harmful constituents. Water pollution is a major problem in the global context [4]. Sometimes pollutants like plant nutrients, bacteria, viruses, pesticides, herbicides, hydrocarbons, heavy metals and other toxic chemicals can enter through the groundwater thereby polluting it. Shallow groundwater is often affected by the land use. The quality of groundwater has been affected through domestic, agricultural and industrial pollution. Nitrates is predominant in western of Delhi [5]. Groundwater in deeper aqui-

Table 1. Location of ground water sampling sites.

Sites	Location	Latitude	Longitude	Altitude above MSL
1.	Artesian well H-block	29°01′31.25′′ N	79°26′15.20′′ E	230 m
2.	H-block (residence)	29°01′31.96′′ N	79°26′16.08′′ E	230 m
3.	I-block near labor colony (residence)	29°00′46.36′′ N	79°26′09.99′′ E	227 m
4.	I-block (DHP)	29°00′45.66′′ N	79°26′11.13′′ E	226 m
5.	K-block near barrier	28°59′51.10′′ N	79°26′39.57′′ E	223 m
6.	Prachin Vanshakti temple Fulsunga road	28°59′25.76′′ N	79°25′49.94′′ E	220 m
7.	Fulsunga camp	28°59′24.09′′ N	79°26′26.83′′ E	220 m
8.	Fulsunga road near Shiv Shakti Dharma Kant	28°59′23.43′′ N	79°25′40.60′′ E	220 m
9.	Fulsunga road near Amogh Enterprises	28°59′23.07′′ N	79°25′19.90′′ E	217 m
10.	Transit camp	28°59′22.50′′ N	79°24′47.96′′ E	217 m
11.	Transit camp residence (DHP)	28°59′22.27′′ N	79°24′47.27′′ E	217 m
12.	Sector-6 near Electromech Pvt Ltd Rudrapur	29°00′15.61′′ N	79°24′43.88′′ E	219 m
13.	HCL chowk	29°00′26.87′′ N	79°24′27.37′′ E	217 m
14.	Matkota temple	29°00′29.21′′ N	79°24′01.08′′ E	223 m
15.	Matkota market	29°00′36.18′′ N	79°24′00.65′′ E	226 m
16.	Behind Ashok Leyland (plot no. 1)	29°01′06.39′′ N	79°23′46.78′′ E	221 m
17.	Behind Ashok (plot no. 3)	29°00′52.78′′ N	79°23′36.81′′ E	220 m
18.	Dineshpur turn	29°01′41.93′′ N	79°24′05.29′′ E	235 m
19.	Chattarpur turn (DHP)	29°01′50.66′′ N	79°23′26.78′′ E	225 m
20.	Chattarpur village (residence)	29°01′38.02′′ N	79°23′16.05′′ E	224 m
21.	Chattarpur village (DHP)	29°01′38.26′′ N	79°23′17.57′′ E	225 m
22.	Horticulture Research Center	29°01′45.44′′ N	79°24′51.58′′ E	233 m
23.	Anandibai temple	29°02′11.07′′ N	79°25′39.05′′ E	230 m
24.	Police station Haldi	29°02′12.82′′ N	79°26′48.07′′ E	237 m

fers beneath the layers of rock or clay that do not let water through has better protection from pollution because it is not directly connected to the surface environment. Contaminants that may be present in source water include : Microbial contaminants such as viruses and bacteria, from sewage treatment plants, septic systems, agricultural livestock operations and wildlife. Inorganic contaminants, such as salts and metals can be naturally occurring or come from urban storm-water runoff (streets and parking lots), industrial or domestic wastewater discharges, oil and gas production, mining or farming. Pesticides and herbicides from a variety of sources such as agriculture, urban storm-water runoff and residential uses. Organic chemical contaminants, including synthetic and volatile organic chemicals are byproducts of industrial prosesses and petroleum production. They can also come from gas stations, urban storm-water runoff and septic systems. Radioactive contaminants can be naturally occurring or can come from oil and gas production, mining activities or medical use.

The degradation of water quality has severe effects in context with drinking, agriculture and industrial purposes. Drinking impure water results in various harmful diseases like diarrhea, blue baby diseases if excess of nitrate is present in water. In industries if water has more hardness due to chlorides and sulfides it is not suitable for the cleaning purposes. In agriculture if water has more salt concentrations then it reduces permeability of soil and infiltration is reduced. More nitrate concentration is harmful for drinking but safe for irrigation purposes. Keeping these facts in view a study on physico-chemical properties of ground water and its suitability for irrigation purpose was carried out in the industrial area of SIDCUL (State Industrial Development Corporation of

Table 2. Values of different parameters for the assessment of suitability of water for irrigation.

Sl. No.	Location	Mg:Ca ratio	EC	TDS	Na%	SAR	ESP	SSP
1.	Artesian well H-block	0.13	340	232.5	63.82	5.06	8.02	52.64
2.	H-block (residence)	0.16	545	278	50.85	3.32	5.80	40.82
3.	I-block near labor colony (residence)	0.19	522.5	310	63.84	6.75	10.08	57.62
4.	I-block (DHP)	0.12	445	262.5	62.66	5.18	8.17	52.29
5.	K-block near barrier	0.36	425	252.5	80.96	8.08	11.64	64.43
6.	Prachin Vanshakti temple Fulsunga road	0.27	442.5	260	61.01	3.31	5.79	43.06
7.	Fulsunga camp	0.14	552.5	330	49.52	2.00	4.05	29.75
8.	Fulsunga road near Shiv Shakti Dharma Kanta	0.28	832.5	520	54.71	2.91	5.26	34.62
9.	Fulsunga road near Amogh Enterprises	0.26	387.5	220	69.38	4.23	6.98	51.34
10.	Transit camp	0.32	580	263.75	64.88	4.64	7.49	48.86
11.	Transit camp residence (DHP)	0.37	320	200	58.29	3.70	6.29	49.45
12.	Sector-6 near Electro-mech Pvt Ltd Rudrapur	0.22	817.5	502.5	63.06	4.38	7.17	47.23
13.	HCL chowk	0.15	370	212.5	63.91	3.85	6.49	48.16
14.	Matkota temple	0.15	422.5	242.5	67.37	3.60	6.16	47.20
15.	Matkota market	0.22	735	437.5	62.93	4.02	6.71	44.70
16.	Behind Ashok Leyland (plot No. 1)	0.29	495	287.5	56.62	3.61	6.17	43.34
17.	Behind Ashok (plot no. 3)	0.20	552.5	325	50.72	2.41	4.59	32.63
18.	Dineshpur turn	0.28	622.5	370	50.61	2.66	5.33	36.19
19.	Chattarpur turn (DHP)	0.20	402.5	235	52.45	2.02	4.06	29.95
20.	Chattarpur village (residence)	0.45	410	235	57.58	2.94	5.30	39.97
21.	Chattarpur village (DHP)	0.43	415	237.5	60.26	3.32	5.79	42.32
22.	Horticulture Research Center	0.29	580	347.5	49.75	2.94	5.30	35.82
23.	Anandibai temple	0.28	580	345	52.43	2.89	5.24	35.92
24.	Police station Haldi	0.27	615	365	52.58	2.11	4.19	29.74

Uttarakhand Limited) of Rudrapur.

Materials and Methods

Study area

The study area is located in SIDCUL (State Industrial Development Corporation Uttarakhand Limited) near Rudrapur of Udham Singh Nagar district. The geographical area of the district is 3055 km^2. It is located between latitude 28°59´22.27´´ to 29°02´12.82´´ N and laterally extends between longitudes 79°23´16.05´´ to 79°26´48.07´´ E. The climate varies from sub-tropical and sub-humid with three distinct seasons i.e. summer, monsoon (rainy season) and winter. The average annual rainfall is 1475 mm.

Sample collection

The water samples for the physico-chemical analysis were collected on 8th November 2014, 14th march 2015 and 11th April 2015 from the deep and shallow hand pumps of the 24 locations (Table 1) of the study area.

Water quality criteria for irrigation

The categorization of the ground water, of SIDCUL area for their suitability for irrigation were studied

Table 3. Irrigation suitability criteria.

Problem	Richard Parameter	Class	Limits	Wilcox Parameter	Class	Limits
Salinity hazards	EC	Low (C_1)	100–250	Percent Sodium	Excellent	< 20
		Medium (C_2)	250–750		Good	20–40
		High (C_3)	750–2250		Permissible	40–60
		Very high (C_4)	2250–5000		Doubtful	60–80
Sodium (alkali hazard)	SAR	Low (S_1)	0–10		Unsuitable	> 80
		Medium (S_2)	10–18		Excellent	<250
		High (S_3)	18–26	EC (µS/cm)	Good	250–750
		Very high (S_4)	>26		Permissible	750–2000
					Doubtful	2000–3000

with the help of criteria given by Richard [6], Wilcox [7] and Wescot and Ayers [8]. The Richard criteria for irrigation was based on Salinity hazards (µS/cm) and Alkali hazards (Sodium Absorption Ratio). The Wilcox criterion for irrigation is based on percent sodium (% Na) and EC (ds/cm). The Wescot and Ayers criteria for irrigation is based on Salinity EC (dS/m), Specific ion toxicity (sodium absorption ratio) and permeability (SAR and EC). To study the suitability of available water for irrigation, the following categorization parameters were calculated.

Results and Discussion

Ground water quality parameters

Different parameters viz. Mg : Ca ratio, Percent Na, ESP, SAR and SSP were estimated for the assessment of the quality of the ground water from the SIDCUL region. It was found from Table 2 that the Mg : Ca ratio value was found minimum in water sample near I-block with a value of 0.12 while maximum value of 0.45 was found in water sample near Chhatarpur village (residence). The percent sodium value varied from 49.52 (minimum) in water sample at Fulsunga camp to 80.96 (maximum) in water sample near K-block. Exchangeable sodium percentage (ESP) value was observed to be minimum as 4.05 in water sample collected from Fulsunga camp and maximum value was observed as 11.64 in water sample collected from K-block. Sodium absorption ratio (SAR) value was observed to minimum as 2.0 for water sample near Fulsunga camp and maximum value of 8.08 at water sample collected near K-block. Soluble sodium percentage (SSP) value was observed to be minimum as 29.74 and maximum as 5.34 at water sample collected near Police station Haldi and Fulsunga road near Amogh Enterprises.

Categorization of water for irrigation
on the basis of criteria
given by Richard

The categorization of the ground water of nearly industrial area of Rudrapur on the basis of criteria given by Richard is given in Table 3.

Classification on the basis of salinity hazards

Table 3 that the ground water at artesian well H-block, H-block residence, I-block near Labor colony, I-block (DHP), K-block near barrier, Prachin Vanshakti temple Fulsunga road, Fulsunga camp, Fulsunga road near Amogh Enterprises, Transit camp, Transit camp (DHP), HCL chowk, Matkota temple, Matkota market, behind Ashok Leyland (plot no. 1), behind Ashok Leyland (plot no. 3), Dineshpur turn, Chattarpur turn (DHP), Chattarpur village (residence), Chattarpur village (DHP), Horticulture Research Center, Anandibari temple, Police station Haldi were found from class C_2 of salinity. The water from these sites showed medium salinity and therefore can be used for irrigation on almost all types of crops and soil the groundwater of Fulsunga road near Shiv Shakti Dharma Kanta and sector-6 near Electromech Pvt Ltd. Ridrapur were found under C_3 class of salinity, which implied that the water from these places was highly saline and

Table 4. Irrigation suitability criteria given by Wescot and Ayers [8].

Problem	Parameter	Class	Limits
		None	<0.70
Salinity (affects the availability of crop water)	EC (ds / m)	Slight to moderate	0.70 –3.0
		Severe	>3.0
	TDS (mg/l)	None	<450
		Slight to moderate	450 –2000
		Severe	>2000
Specific ion toxicity (affects the sensitivity of the crops)	Sodium absorption ratio (SAR)	None	<3.0
		Slight to moderate	3.0–9.0
		Severe	>9.0
Permeability (affects the infiltration rates of water into soil)	SAR and EC (ds/m)	None	0–3 & >0.7 3–6 & >1.2 6–12 & >1.9 12–20 & >2.9
		Slight to moderate	0–3 & 0.7–0.2 3–6 & 1.2–0.3 6–12 & 1.9 –0.5 12–20 & 2.9–1.3
		Severe	0–3 & <0.2 3–6 & <0.3 6–12 & <0.5 12–20 & <1.3

therefore, should not be used for irrigation without proper drainage system. The good salt tolerated crop should be grown if irrigated with these waters.

Classification on the basis of sodium (alkali) hazards

Table 3 shows following classification : The artesian well H-block, H-block residence, I-block near Labor colony, I-block (DHP), K-block near barrier, Prachin Vanshakti temple, Fulsunga road, Fulsunga camp, Fulsunga road near Shiv Shakti Dharma Kanta, Fusunga road near Amogh Enterprises, Transit camp, Transit camp (DHP), Sector-6 near Electromech Pvt Ltd, Rudrapur, HCL chowk, Matkota temple, Matkota market, behind Ashok Leyland (plot no. 1), behind Ashok Leyland (plot no. 3), Dineshpur turn, Chattarpur turn (DHP), Chattarpur village (residence), Chattarpur village (DHP), Horticulture Research Center, Anandibai temple, Police station Haldi were under S_1 class of alkalinity hazard which implied that the water at these locations were low sodium in nature and could be used for irrigation on almost all type of soil with less harm to soil and crop.

Categorization of water for irrigation on the basis of criteria given by Wilcox [7]

The categorization of ground water of the industrial area of Rudrapur, on the basis of criteria given by Wilcox [7] is given in Table 3.

Classification on the basis of percent sodium

Table 3 shows that the water of H-block (residence), Fulsunga camp, Fulsunga road (near Shiv Shakti Dharma Kanta), Transit Camp residence (DHP), behind Ashok Leyland (plot no. 1), behind Ashok Leyland (plot no. 3), Dineshpur turn, Chattarpur turn (DHP), Chattarpur village (residence), Horticulture Research Center, Anandibai temple, Police station Haldi were found under permissible category for irrigation. Artesian well H-block, I-block near labor colony (residence), I-block (DHP), Prachin Vanshakti temple Fulsunga road, Fulsunga road near Amogh Enterprises, Transit camp, Sector-6 near Electromech Pvt, Ltd, Rudrapur, HCL chowk, Matkota temple, Matkota market, Chattarpur village (DHP) were found under doubtful category for irrigation. The water of

K-block near barrier was found under unsuitable category for irrigation.

Classification on the basis of electrical conductance (EC)

It was observed from Table 3, on the basis of electrical conductivity criteria, the ground water at Artesian well H-block, H-block (residence), I-block near labor colony (residence), I-block (DHP), K-block near barrier, Prachin Vanshakti temple Fulunga road, Fulsunga camp, Fulsunga road near Amogh Enterprises, Transit camp, Transit camp residence (DHP), HCL chowk, Matkota temple, Matkota market, behind Ashok Leyland (plot no. 1), behind Ashok Leyland (plot no. 3), Dineshpur turn, Chattarpur turn (DHP), Chattarpur village (residence), Chattarpur village (DHP), Horticulture Research Center, Anandibai temple, Police Station Haldi were found under good category for irrigation. The ground water of Fulsunga road (near Shiv Shakti Dharma Kanta), sector-6 near Electromech Pvt Ltd, Rudrapur were found under permissible category for irrigation.

Categorization of water for irrigation on the basis of criteria given by Wescot and Ayers [8]

The categorization of water samples collected from nearby areas of industrial area of Rudrapuron the basis of criteria given by Wescot and Ayers [8] is given in Table 4.

Classification on the basis of salinity

Table 4 shows that on the basis of EC, the ground water at Artesian well H-block, H-block (residence), I-block near labor colony (residence), I-block (DHP), K-block near barrier, Prachin Vanshakti temple Fulsunga road, Fulsunga camp, Fulsunga road near Amogh Enterprises, Transit camp, Transit camp residence (DHP), HCL chowk, Matkota temple, Matkota market, Behind Ashok Leyland (plot no. 1), Behind Ashok Leyland (plot no. 3), Dineshpur turn, Chattarpur turn (DHP), Chattarpur village (residence), Chattarpur village (DHP), Horticulture Research Center, Anandibai temple, Police station Haldi were having none class therefore the water at these points not having any effect on the availability of water to the crop. The ground water at Fulsunga road (near Shiv Shakti Dharma Kanta), sector 6 near Electromech Pvt Ltd, Rudrapur were found to have slight to moderate effect on availability of water to crops. On the basis of TDS, the ground water at Artesian well H-block, H-block (residence), I-block near labor colony (residence), I-block (DHP), K-block near barrier, Prachin Vanshakti temple Fulsunga road, Fulsunga camp, Fulsunga road near Amogh Enterprises, Transit camp, Transit camp (DHP), HCL chowk, Matkota temple, Matkota market, behind Ashok Leyland (plot no. 1), behind Ashok Leyland (plot no. 3), Dineshpur turn, Chattarpur turn (DHP), Chattarpur village (residence), Chattarpur village (DHP), Horticulture research Center, Anandibai temple, police station Haldi was having none class therefore water at these sampling site have no effect on the availability of water to crop. The ground water at Fulsunga road near Shiv Shakti Dharma Kanta, sector-6 near Electromech Pvt Ltd. Rudrapur was under slight to moderate class on the basis of TDS. This would affect moderately on the filtration rate of water into the soil when used for irrigation.

Classification on the basis of specific ion toxicity

On the basis of SAR ratio the ground water at Fulsunga camp, Fulsunga road near Shiv Shakti Dharma Kanta, behind Ashok Leyland (plot no. 3), Dineshpur turn, Chattarpur turn (DHP), Chattarpur village (residence), Horticulture research Center, Anandibai temple, Police station Haldi were having no toxicity effect. The water at Artesian well H-block, H-block (residence), I-block at labor colony (residence), I-block (DHP), K-block near barrier, Prachin Vanshakti temple Fulsunga road, Fulsunga road near Amogh Enterprises, Transit camp, Transit camp residence (DHP), Sector-6 near Electromech Pvt Ltd. Rudrapur, HCL chowk, Matkota temple, Matkota market, behind Ashok Leyland (plot no. 1), Chattarpur village (DHP) were having slight to moderate effect of ion toxicity.

Classification on the basis of permeability

On the basis of combined effect of SAR and EC, the

ground water at Fulsunga road near Shiv Shakti Dharma Kanta was not having any effect on the infiltration rate of water into the soil. The ground water at Fulsunga camp, behind Ashok Leyland (plot no. 3), Dineshpur turn, Chattarpur turn, Chattarpur village (residence), Horticulture Research Center, Anandibai temple, police station Haldi, Artesian well H-block, H-block residence, I-block (DHP), Prachin Vanshakti Mandir, Fulsunga road near Amogh Enterprises, Transit camp, Transit camp (DHP), Sector-6 in front of Electromech Pvt Ltd Rudrapur, HCL chowk, Matkota temple, Matkota market, behind Ashok Leyland (plot no. 1), Chattarpur village (DHP), I-block near labor colony were found to have slight to moderate effect on infiltration rate of water into the soil. The ground water at K-block near barrier was found severe effect on infiltration rate of water into the soil.

Conclusion

It can be summarised that two out of 24 water samples were found under C_3 class of salinity which implied that the water from these places was highly saline according to Richard [6].

One out of 24 and two out of 24 were found to be unsuitable on the basis of percent sodium and under permissible category on the basis of electrical conductivity according Wilcox [7]. Two out of 24 were found to have slight to moderate effect on availability of water to crops on the basis of salinity and Nine out of 24 water samples were having no toxicity effect while other samples were having slight to moderate effect of ion toxicity on the basis of SAR according Wescot and Ayers [8].

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